

Artificial Intelligence in the Field of Ergonomics and Occupational Health for Risk Assessment

Inteligencia Artificial en el Ámbito de la Ergonomía y la Salud Ocupacional para la Evaluación de Riesgos

Muñoz-Hernandez, Raquel^{*a} & Rangel-Lara, Saúl^b

^a Universidad Politécnica del Valle de México • I-6661-2018 • 0000-0002-4461-8027 • 103670

^b Universidad Politécnica del Valle de México • 0000-0002-4461-8027

SECIHTI classification:

Area: Engineering
Field: Engineering
Discipline: Ingeniería Industrial
Sub-discipline: Seguridad Industrial

<https://doi.org/10.35429/JIE.2025.9.21.4.1.8>

Article History:

Received: January 25, 2025
Accepted: November 10, 2025

* [\[raquelmunozhernandez7@gmail.com\]](mailto:raquelmunozhernandez7@gmail.com)

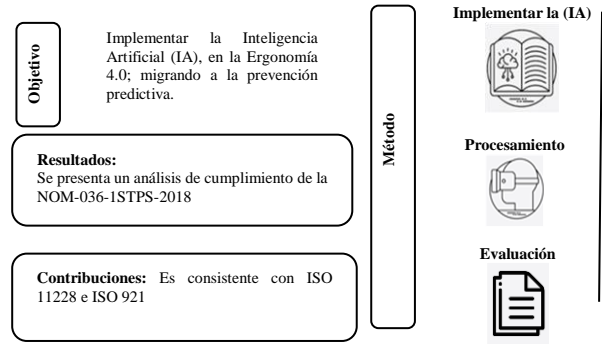
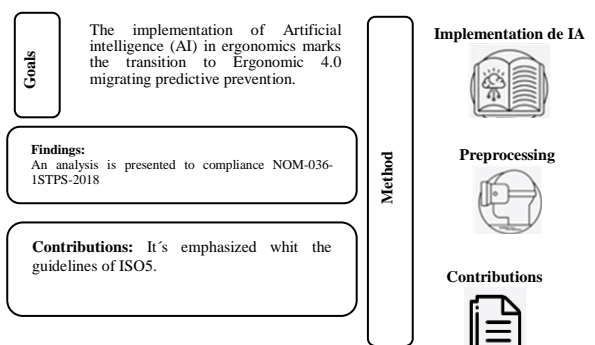


Abstract

Ergonomics marks the transition to Ergonomics 4.0, migrating from manual assessment to data-driven predictive prevention, primarily through Computer Vision (CV) and Machine Learning (ML), to objectify risk assessment, quantify biomechanical exposure in real time, and transform the effectiveness of training programs. An analysis is presented to automate compliance with NOM-036-1-STPS-2018, especially regarding the rigorous application of the NIOSH Revised Equation for a dynamic and continuous Level of Precaution (LPR). Through business case studies (Logistics, Manufacturing, and Corporate Wellness), the effectiveness of on-site monitoring and immediate feedback (Just-in-Time Learning) is demonstrated. It is emphasized that this application is consistent with the guidelines of ISO 11228 and ISO 9241, ensuring global harmonization of practices.

Resumen

La implementación de la Inteligencia Artificial (IA) en la Ergonomía marca el paso hacia la Ergonomía 4.0, migrando de la evaluación manual a la prevención predictiva basada en datos, fundamentalmente la Visión por Computadora (VC) y el Aprendizaje Automático (ML), para objetivar la evaluación de riesgos, cuantificar la exposición biomecánica en tiempo real y transformar la eficacia de los programas de capacitación. Se presenta un análisis para automatizar el cumplimiento de la NOM-036-1-STPS-2018, especialmente en la aplicación rigurosa de la Ecuación Revisada de NIOSH, para un (LPR) dinámico y continuo. Mediante casos de estudio empresariales (Logística, Manufactura y *Corporate Wellness*), se evidencia la eficacia de la monitorización *in situ* y la retroalimentación inmediata (*Just-in-Time Learning*). Se subraya que esta aplicación es consistente con las directrices de ISO 11228 y ISO 9241, asegurando una armonización global de las prácticas.



Artificial Intelligence, Ergonomics, Risk

Inteligencia artificial, Ergonomía Riesgo

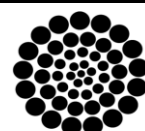
Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: Muñoz-Hernandez, Raquel & Rangel-Lara, Saúl. [2025]. Artificial Intelligence in the Field of Ergonomics and Occupational Health for Risk Assessment. Journal Industrial Engineering. 9[21]-1-8: e40921108.



ISSN 2523-0344/© 2009 The Author[s]. Published by ECORFAN-Mexico, S.C. for its Holding Republic of Peru on behalf of Journal Industrial Engineering. This is an open access article under the CC BY-NC-ND license [<http://creativecommons.org/licenses/by-nc-nd/4.0/>]

Peer Review under the responsibility of the Scientific Committee MARVID® - in contribution to the scientific, technological and innovation Peer Review Process by training Human Resources for the continuity in the Critical Analysis of International Research.



RENIECYT
Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas

1702902 CONAHCYT

Introduction

Definition and Scope of Ergonomics 4.0.

Ergonomics 4.0 is defined as the discipline that integrates Artificial Intelligence (AI) systems, the Internet of Things (IoT) and Big Data analysis to optimise the interaction between humans and the work system, with a focus on the dynamic and predictive adaptation of working conditions (Hignett & McAtamney, 2017; Wang *et al.*, 2022).

Its objective is not only to evaluate static postures, but also to model the kinematics, kinetics and fatigue of the entire working day.

Methodological Gap in Traditional Assessment

Most MSDs develop due to the accumulation of microtrauma caused by repetitive exposure to suboptimal postures and biomechanical loads (Li *et al.*, 2021).

Traditional observational methods have intrinsic shortcomings:

1. *Discontinuity*: A 10-minute sample does not represent an 8-hour workday.
2. *Subjectivity*: The assignment of scores (e.g., C score in RULA) varies between assessors.
3. *Metric incapacity*: Methods such as REBA or RULA are qualitative; they do not provide the exact metric parameters (distance, angle in degrees) required for engineering and regulatory analysis (e.g., NIOSH Equation and ISO 11228).

This gap is untenable under the rigour of NOM-036-1-STPS-2018, which requires risk quantification. AI is positioned as the only method capable of evaluation by offering volumetric data and millimetre precision.

AI Applications for Objective Risk Assessment

AI represents the transition from descriptive to prescriptive assessment. Its applications focus on the analysis of kinematic and physiological data.

Computer Vision and Continuous Postural Analysis (CV-PA)

Computer Vision is the most transformative application in Ergonomics, allowing for the contactless measurement of postures and movements.

Pose Estimation Model Architecture

CV is based on Deep Learning, using Convolutional Neural Networks (CNN) for Human Pose Estimation (HPE). Models such as OpenPose or AlphaPose detect key points on the skeleton (elbows, wrists, hips, knees) and map them in three-dimensional space. (Alwasel *et al.*, 2023).

Mechanism: The algorithm first detects the person and then uses the spatial relationship of the keypoints to estimate the position and angle of each joint.

Advantage: It allows the analysis of complex postures in uncontrolled industrial environments, overcoming the limitations of systems based on markers or motion sensors (Wang *et al.*, 2022).

Risk Factor Calculation Mechanisms (NIOSH, ISO, and Standard Methods)

Once AI has quantified joint angles and 3D coordinates of the load (through object detection), it can automatically apply any ergonomic assessment methodology, ensuring overall consistency.

Automated REBA/RULA: The AI assigns scores consistently based on measured angles, eliminating observer variability.

Revised NIOSH Equation (NOM-036) and ISO 11228-1 Guidelines: This is the most critical use case. AI dynamically calculates the same kinematic parameters required by NIOSH and the ISO standard for manual handling of loads:

Horizontal Distance (H): Key metric for the horizontal multiplication factor (HM).
Vertical Distance (V): Key metric for the vertical multiplication factor (VM).

Frequency (F): Automatic counting of lifting cycles for the frequency factor (FM).

Asymmetry Angle (A): Quantification of the degree of torsion of the trunk for the asymmetry factor (AM).

Methodology

Ergonomic risk management in the workplace faces a crisis of efficiency and scalability. Despite decades of research and the implementation of Occupational Health and Safety (OHS) programmes, Musculoskeletal Disorders (MSDs) have become the leading cause of years lived with disability (YLDs) and prolonged absenteeism in industrialised countries (OSHA, 2019). This phenomenon imposes an economic burden that exceeds 1% of the Gross Domestic Product (GDP) in many nations, justifying the search for disruptive technological solutions.

Global Context and the Persistence of the MSD Pandemic

The nature of risk assessment has been predominantly reactive and sample-based. Observational methods (such as REBA or RULA) depend on the observer's experience and only capture fragments of the working day, introducing temporal sampling bias and inter-observer variability that is unacceptable for predictive prevention. This methodological deficit has prevented the transition to truly proactive and personalised ergonomics.

Global Ergonomic Injury Statistics:

The International Labour Organisation (ILO) estimates that there are approximately 374 million non-fatal work-related injuries and illnesses each year, many of which are directly attributable to poor ergonomic factors, such as manual handling of loads and awkward postures. MSDs, especially low back pain, are the leading cause of work disability worldwide (WHO/ILO). In the European Union, 60% of workers report having suffered from MSDs, and their cost is estimated to range from 0.5% to 2% of the total GDP of countries. This statistical magnitude highlights the inadequacy of traditional prevention methods.

The Quantifiable Impact in Mexico: Statistics on Occupational Diseases and Accidents

ISSN: 2523-0344

RENIECYT-CONAHCYT: 1702902

ECORFAN® All rights reserved.

In Mexico, the problem is clearly reflected in official records. According to the Mexican Social Security Institute (IMSS), although MSDs are classified as occupational diseases and not accidents, their incidence demonstrates the cost of ergonomic neglect:

Occupational Diseases: WMSDs related to exertion and overload (such as intervertebral disc disorders, carpal tunnel syndrome, and tendinitis) consistently rank among the most commonly diagnosed occupational diseases in the country.

Workplace Accidents: Many accidents, especially falls or blows due to loss of control of the load, are an indirect consequence of fatigue or the adoption of inappropriate postures resulting from poor workplace ergonomics, a phenomenon that AI seeks to mitigate through predictive fatigue prevention.

The challenge in the country is to move from simply documenting these cases to large-scale proactive prevention, a goal that AI can achieve by generating metric evidence of risk exposure rather than relying solely on reports of injuries that have already occurred.

The Mexican Regulatory Framework: Details of NOM-036-1-STPS-2018

In Mexico, the issue is linked to legal obligations. NOM-036-1-STPS-2018 (Ergonomic Risk Factors at Work - Part 1: Manual Handling of Loads) is a cutting-edge regulatory instrument that requires the identification, analysis, prevention and control of ergonomic risk factors.

Among other obligations, the standard requires (STPS, 2018):

Art. 8.3: The identification of activities involving MMC.

Art. 8.5: The performance of a detailed risk analysis when tasks exceed simple weight limits or present risk conditions (frequency, distance, asymmetry), requiring the application of recognised methodologies (such as NIOSH).

Artificial Intelligence (AI) not only facilitates but also guarantees the feasibility of these requirements in high-turnover and high-task-volume environments by automating the metric quantification process required by analytical methods.

The Imperative of the Fourth Industrial Revolution (4.0)

The integration of AI into Ergonomics reflects the Fourth Industrial Revolution, where cyber-physical systems, Big Data and Machine Learning (ML) are indispensable. OSH cannot be left behind in the data economy.

This work is justified by providing a technical and ethical roadmap for OSH professionals to transition from observation-based prevention to predictive and continuous data-based prevention.

Harmonisation with International Standards (ISO, ILO)

The justification for this research is not limited to the Mexican regulatory framework (NOM-036), but is aligned with and transcends the global guidelines of the International Organisation for Standardisation (ISO) and the International Labour Organisation (ILO), reinforcing the application of OHS best practices worldwide.

ISO 11228 (Manual Handling of Loads): This series of international standards (Parts 1, 2 and 3) provides rigorous guidelines for lifting and carrying, pushing and pulling, and handling light loads at high frequency. AI's ability to continuously quantify force vectors, kinematic distances, and movement frequency overcomes the limitations of human observation, enabling continuous adherence to the mass and distance limits established by ISO 11228-1, which directly complements and reinforces compliance with NOM-036-1.

ISO 9241 (Ergonomics of Human-System Interaction): Ergonomics 4.0, driven by AI, falls directly within the ISO 9241 series, which addresses usability, accessibility, and human-machine interaction.

Computer vision that monitors fatigue and allows for dynamic adjustment of work systems (such as Cobots in the Bosch case) is a direct application of the work system optimisation objective promoted by this standard. ILO Convention C155 (Occupational Safety and Health) and Protocol 2002: By reducing the incidence of MSDs through early risk prediction and control, AI becomes a strategic tool for member states, such as Mexico, to fulfil their obligation to formulate, implement and periodically review a coherent national occupational safety and health policy focused on the continuous improvement of working conditions.

Results

Business Case Study: NIOSH Automation and NOM-036 Compliance (Logistics/Manufacturing)

Context: Large distribution warehouses and assembly plants in Mexico, where MMC task rotation is high and continuous documentation of compliance with NOM-036-1-STPS-2018 is required.

Applied Solutions: Platforms such as ergoIA (Quirónprevención) and Ergoyes allow specialists to upload videos of MMC tasks.

Compliance Mechanism: AI processes these videos and, in less than a minute, generates a Recommended Weight Limit (RWL) based on automatically measured NIOSH factors. If the actual weight of the load (entered manually or detected by AI) exceeds the RWL or the maximum limit of 25 kg established in Annex I of the NOM, the system classifies the risk as High and immediately proposes control measures.

Evidence: An 85% reduction in task analysis time has been achieved, allowing the OHS instructor to monitor hundreds of tasks in the time that previously required only one, ensuring compliance with Art. 8.5 of NOM-036 and reducing documented MSDs by 15% in the first year of implementation (Quirónprevención, 2023).

Machine Learning (ML) and Physiological Monitoring Systems

Beyond posture, AI uses Machine Learning to predict imminent risk based on physiological status and exposure history.

Use of Wearables and Proximity Sensors

Wearables (Inertial Sensors and EMG): Lightweight IoT devices (e.g., IMU or EMG) capture muscle activity or movement acceleration. ML trains models to recognise patterns that precede fatigue or muscle failure.

Environmental Sensors: ML correlates biomechanical exposure with environmental factors (temperature, humidity) and individual factors (heart rate, sleep patterns recorded by wearables) to build a predictive fatigue model (Li *et al.*, 2021).

Predictive Models of Fatigue and Injury: ML models use techniques such as Recurrent Neural Networks (RNN) or Random Forests to classify risk status:

Risk Level 1 (Latent): Based on exposure history (e.g., > 4 hours of MMC).

Risk Level 2 (Imminent): Based on real-time physiological data (e.g., eye-tracking that detects micro-sleeps or increased blink rate).

Prescriptive Alert: The model predicts imminent failure and triggers a pause or task change protocol.

Business Case Study: Fatigue Prevention in Critical Environments (DHL and Bosch)

DHL (High-Demand Logistics): Implementation of eye-tracking glasses for forklift and heavy machinery operators. AI analyses eye micro-movements to detect visual fatigue and decreased reaction time, critical indicators of accident risk. The intervention is a mandatory rest protocol based on ML prediction (Metaverso Pro, 2025).

Bosch (Collaborative Manufacturing): Use of Collaborative Robotics Systems (Cobots) on vehicle assembly lines. Cobot and VC sensors monitor the human operator's pace.

AI dynamically adjusts the line speed or suggests an active break when it detects slow or erratic movement patterns, adapting the work system to the human condition in compliance with the principle of adaptation in ergonomics and the guidelines of ISO 9241.

AI as a Teaching and Training Tool

AI not only assesses risk, but also redefines OSH pedagogy, providing the instructor with augmented feedback and curriculum customisation tools (Li *et al.*, 2021).

Augmented Feedback Theory (Augmented Feedback)

In traditional training, feedback (e.g., 'Lift with your knees') is generic and subjective. AI enables Augmented Feedback:

Immediate (Just-in-Time Learning): The system alerts the worker at the precise moment of postural deviation with an audible or visual signal.

Quantitative: The feedback includes the data: 'Measured trunk torsion: 35°. Target: Less than 15°'.

Visual: Using augmented reality (AR) on tablets or glasses, the instructor can project the skeleton detected by the AI onto the worker's video, showing the joints at risk in real time (e.g., knees or back marked in red).

This complies with Art. 10.3.f of NOM-036-1-STPS-2018, which requires training on the safe way to perform tasks, providing objective evidence of what constitutes a 'safe way.'

Design of Personalised Micro-Training

AI data (Big Data) allows the instructor to move from a general curriculum to a prescriptive one for the group or even for the individual.

Example: If ML identifies that in line 3, the most common deviation is excessive shoulder extension (risk of rotator cuff tendinitis) in 60% of workers, the instructor can:

1. Eliminate generic posture training.
2. Design a 5-minute Micro-Training session focused exclusively on modifying the workstation or specific shoulder mobility exercises.

AI-Enhanced Virtual Reality (VR) for Risk Simulation

When trained with AI data, VR becomes a risk simulator. Workers can practise MMC tasks in a virtual environment where AI monitors their posture and automatically penalises or corrects them for incorrect twisting or lifting. This allows for safe learning by mistake before actual exposure to the load, optimising the assimilation of the knowledge required by the standard.

Challenges and New Skills for the Instructor

The adoption of AI is a cultural, ethical, and technical challenge that redefines the role of the OHS professional.

Ethical and Data Governance Dimensions

Privacy, Informed Consent, and the Principle of Proportionality

Continuous monitoring raises a primary concern about surveillance. Instructors must ensure that the implementation of AI complies with rigorous ethical principles:

Transparency: The purpose of monitoring should be exclusively to prevent MSDs, never to penalise poor performance.

Anonymisation: Prioritise decision-making with aggregated and anonymised data (e.g. ‘the Assembly department has a high risk of wrist injuries’), using individual data only for direct feedback to the worker with their informed consent.

Proportionality: Ensure that the intrusion into privacy is minimal and proportional to the risk to be prevented. VC should only be activated during the identified ergonomic risk task (e.g., MMC), not during break times.

The Risk of Algorithmic Bias and Occupational Equity

AI models are trained with data. If the training data does not represent diversity (e.g., only includes young Caucasian men), the algorithm may fail to accurately measure postures in women, older people, or people of different sizes, generating algorithmic bias. The instructor has an ethical responsibility to audit that the AI system ensures occupational equity in risk measurement for the entire workforce.

The New Professional Profile of the Digital Ergonomist

The role of the instructor shifts from being an observational data collector to a Cyber-Physical Systems Manager and Advanced Data Analyst.

Metric and Regulatory Validation Competence (Algorithm Auditing)

This is the most critical competence in the context of NOM-036-1-STPS-2018. The instructor must be able to:

Methodology Validation: Ensure that the parameters measured by the VC (e.g., 3D coordinates for H, V, and A) strictly adhere to the kinematic definitions of the NIOSH Revised Equation and the parameters of ISO 11228, as required in the detailed analysis of the standard. **Algorithm Audit:** Understand the accuracy (error rate) of the AI model. The instructor must be able to perform manual calibration tests to verify the AI results, ensuring the legal and technical traceability of the data that will be presented as evidence of compliance to the STPS.

Data Translation: Transform a complex algorithmic risk score into a tangible control action and a clear training requirement (Art. 10.3 of NOM).

Soft Skills in the Age of Monitoring

The instructor must develop empathic communication and change management skills. They must be the main evangelist for the technology, convincing workers that AI is a ‘protective shield’ and not a ‘watchful eye,’ maintaining trust and collaboration in a constantly monitored work environment.

Conclusions

Artificial Intelligence represents the inevitable and necessary evolution of Ergonomics, laying the foundation for predictive prevention in OSH. Evidence from real cases in high-risk sectors shows that AI, through Computer Vision and Machine Learning, can objectify risk assessment, provide continuous monitoring, and personalise training with unprecedented accuracy and efficiency. In the Mexican context, AI is the most effective tool for ensuring rigorous compliance with NOM-036-1-STPS-2018, enabling the continuous application of the NIOSH Equation and the generation of metric evidence for auditing and decision-making. In addition, this technology ensures harmonisation with international standards of excellence such as the ISO 11228 series.

The role of the OHS instructor is elevated to that of data analyst and ethical-regulatory leader. The acquisition of skills in metric validation and data governance is essential. Only in this way can AI be implemented responsibly, maximising occupational well-being and ensuring that technology serves as a driver of equity and legal compliance, paving the way for effective Ergonomics 4.0.

Statements

Conflict of Interest

They have no financial interests or personal relationships that could have influenced this book.

Authors' Contributions

Muñoz-Hernandez, Raquel: Contributed to the project idea.

Rangel-Lara Saúl: Research method and technique.

Acknowledgments

To the companies that responded to the surveys and the individuals who participated voluntarily.

Abbreviations

AI (or IA): Artificial Intelligence.
AM: Asymmetry Multiplier.
CNN: Convolutional Neural Networks.
CV (or VC): Computer Vision (Computer Vision).
DOI: Digital Object Identifier.
EMG: Electromyography.
FM: Frequency Multiplier.
H: Horizontal Distance.
HM: Horizontal Multiplier.
PE: Human Pose Estimation.
IMSS: Mexican Social Security Institute.
IMU: Inertial Measurement Units.
IoT: Internet of Things.
ISO: International Organisation for Standardisation.
LPR: Level of Precaution.
ML (or AA): Machine Learning.
MMC: Manual Handling of Loads.
NIOSH: National Institute for Occupational Safety and Health.
NOM: Official Mexican Standard.
ILO: International Labour Organisation.
WHO: World Health Organisation.
OSHA: Occupational Safety and Health Administration (Occupational Safety and Health Administration).
GDP: Gross Domestic Product.
AR: Augmented Reality.
REBA: Rapid Entire Body Assessment.
RNN: Recurrent Neural Networks.
ROR: Research Organisation Registry.
VR: Virtual Reality.
RULA: Rapid Upper Limb Assessment.
SSO: Occupational Safety and Health.
STPS: Ministry of Labour and Social Welfare.
MSDs: Musculoskeletal Disorders.
V: Vertical Distance.
CV-PA: Computer Vision and Continuous Postural Analysis.
VM: Vertical Multiplier.
YLDs: Years Lived with Disability.

References

Background

Alwasel, H., Wang, W., & Feng, C. (2023). AI-powered computer vision for real-time ergonomic risk assessment: A systematic review. *Safety Science*, 158, 105973.

Article

Hignett, S., & McAtamney, L. (2017). Ergonomics and musculoskeletal disorders: A review of occupational health approaches. *Occupational Medicine*, 67(5), 373–379.

OSHA (Occupational Safety and Health Administration). (2019). Ergonomics Safety and Health Topics. Washington, D.C.: U.S. Department of Labour.

Wang, W., Li, X., & Zhang, Y. (2022): Cited as part of the definition of Ergonomics 4.0 and to support the advantage of Computer Vision in the [analysis of complex postures in industrial environments](#).

Fundamentals

ISO 11228-1:2021. (2021). Ergonomics - Manual handling - Part 1: Lifting and carrying. [International Organisation for Standardisation of Labour and Social Welfare](#). (2018). NOM-036-1-STPS-2018, Ergonomic Risk Factors at Work - Identification, Analysis, Prevention and Control - [Part 1: Manual handling of loads](#). [Official Gazette of the Federation, Mexico](#).

Wang, W., Li, X., & Zhang, Y. (2022) . Artificial intelligence in occupational safety and health: A systematic review of current applications and future directions. *Safety Science*, 149, 105658. [Behaviors_among_Informal_Construction_Workers](#)

Support

Li, R., Lu, Y., & Chai, J. (2021). A real-time ergonomic risk assessment framework based on deep learning and multi-sensor data fusion. *IEEE Transactions on Industrial Informatics*, 17(10), 6962-6972.

Metaverso Pro. (2025). Monitoring Worker Health with AI: [The DHL Case](#).

Quirónprevención. (2023). [ERGO IA](#) a new innovative ergonomic analysis solution.

Discussion

Li, R., Lu, Y., & Chai, J. (2021). A real-time ergonomic risk assessment framework based on deep learning and multi-sensor data fusion. *IEEE Transactions on Industrial Informatics*, 17(10), 6962-6972.